ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 15, No. 1. 2009

Submerged Arc Welding with Mixed into the Flux Materials Aiming to Obtain Hardened after Tempering Layer

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Received 15 September 2008; accepted 22 October 2008

The layers obtained by overlay welding of Ст3 steel with Св 08 wire under AMS1 flux mixed with graphite, chromium, molybdenum, WC – 8 % Co, Fe – 70 % Mn, modifiers SiCaBa and SB5 powder are investigated. Milled glass, unused grinding wheels SiC and B_4C and hard metal T15K6 powder was used for overlay welding instead of a flux. Effect of overlay welding composition on the layers microstructure and hardness as well as hardness change due to tempering at 500 °C – 650 °C temperatures are investigated. Abrasive wear tests were carried out and they showed that wear resistance of surfacing layers was higher than that of hardened tool steels. Use of secondary raw materials for overlay welding allows to obtain hard enough and high quality layers.

Keywords: powder, overlay welding, hardness, tempering, wear.

1. INTRODUCTION

The deposition of surfacing layers by welding techniques have been widely applied commercially in a wide range of industries in order to improve the wear resistance of the parts [1, 2]. The hardfacing layer producted by Fe-Ti-V-Mo-C hardfacing materials possess much higher wear resistance and a lower friction coefficient. The plough points with welded front and rear surfaces with Fe-C-Cr-Nb-Mo-W-B alloys wear (their mass) 35 % slower than the new points and they shrink also 6 times slower.

The influence of the composition and heat treatment of overlays on the abrasive wear resistance of iron base hardfacing alloy overlays is reported [3]. Overlays were deposited using a shielded metal arc welding process on structural steel using two commercial hardfacing electrodes, i. e., Fe – 6 % Cr – 0.7 % C and Fe – 32 % Cr – 4.5 % C. It was found that the wear resistance of the high Cr-C coating is better than the low Cr-C hardfacing under indentical conditions.

The abrasive wear of machine parts and tools used in the mining, earth moving and transporting of mineral materials can be lowered by filler wire welding of hardfacing alloys [4]. The microstructures of Fe-Cr-C and Fe-Cr-C-Nb/Ti hardfacing alloys and deposits and those of newly developed Fe-Cr-C-B and Fe-Ti-C-B ones are described. They show up to 85 vol. % of primarily solidified coarse hard phases, i. e., carbides of MC, M_7C_3, M_3C – type and borides of MB_2 M_3B_2, $M_{23}B_6$ – type, which are embedded in a hard eutectic. This itself consists of eutectic hard phases and a martensitic or austenitic metal matrix. The newly developed Fe-Cr-C-B alloys reach hardness values of up to 1200 HV and are harder than all purchased ones.

The metallurgical behavior of B_4C in the iron-based surfacing alloy during plasma transferred arc (PTA) Fe-B_4C composite powder surfacing was investigated and discussed in paper [5]. The B_4C particles can only remain in the deposited coating when the surfacing current is little enough. With the increasing of employed surfacing current more and more B_4C particles will be fully melted and reacted with the liquid iron-based alloys. Most of the B_4C particles will be fully melted and reacted with iron-based alloy during the PTA powder surfacing while 200 A or greater surfacing current is used. Furthermore, most of the C in B_4C particles are transferred to graphite rather than reacted with Fe to be carbides during the processing under the Fe-B_4C composite powder PTA surfacing conditions.

The effect of alloying element powder additions on the microstructure and toughness of weld metals an API HSLA-70 line – pipe steel produced by submerged arc welding technique has been investigated [6]. It shows that the addition of Mo in the range 0.817 wt. % – 0.881 wt. % resulted in a decrease of fracture appearance transition temperature (FATT) and an increase of impact toughness. The beneficial effect of Mo is due to the formation of predominant acicular ferrite and granular bainite, at the expense of ferrite with second phase and grain boundary ferrite in weld metal. The combined presence of Ni (2.03 wt. % – 2.91 wt. %) and Mo (0.7 wt. % – 0.995 wt. %) in the weld metal leads to a high volume fraction of fine acicular ferrite with good toughness, since the amount of both second phase and grain boundary ferrite are reduced. When Ni is added alone in the range of 2.03 wt. % – 3.75 wt. %, the weld metal shows a lower toughness and increased FATT, due to a lower of acicular ferrite and a high volume fraction second phase.

A study [7] was conducted on the effect of flux composition for the microstructure and tensile properties of a submerged arc welded AISI 1025 steel. Three flux compositions were used with a low carbon electrode. The yield and ultimate tensile strengths of welds for TiO_2 containing fluxes increase with formation of acicular ferrite. The elongation and area reduction percentages are reduced by the inclusion percentage of welds.

Aiming to obtain wear resistant layers, structural steels are subjected to overlay welding with electrodes which cover contains carbides forming elements. There is a lack of investigation devoted to formation of alloyed layer by

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arc welding using the flux mixed with materials containing alloying elements.

A lot of compositions alloyed by various elements are used for overlay welding of steels [1, 2]. Many steels are overlay welded by alloys containing chromium as a main alloying element [3, 4, 10, 11] because chromium is cheaper in comparison with tungsten, molybdenum and other elements.

The objective of this research is to study alloyed layer by overlay arc automatic welding with low carbon wire and the using flux mixed with materials powder, and to determine effect of tempering temperature on the hardness of surfacing layers.

2. EXPERIMENTAL

Specimens (6×10×60) mm of the structural steel Ст3 (Russian grade) (0.14 % – 0.22 % C; 0.12 % – 0.3 % Si; 0.4 % – 0.65 % Mn) were subjected to overlay welding in the device assembled from the lathe and welding semi-automatic machine [8]. Flux or milled glass powder mixed with powder of other materials was spread over the Ст3 steel surface and melted by continuously supplied 1.2 mm diameter welding wire Св 08 (Russian grade) (<0.09 % C; <0.1 % Si; 0.5 % Mn) arc. The AMS1 flux containing more than 50 % MnO and SiO_2 was used. Some experiments were carried out using milled windows glass or glass package powder, which main component is SiO_2, instead of the flux AMS1.

3. RESULTS AND DISCUSSION

Layers of various microstructures (Fig. 1) were obtained in overlay welding of the Ст3 steel by Св 08 wire under the AMS1 flux mixed with variuos amounts of chromium and graphite powder. Addition of graphite only into the flux enabled to obtain troostite microstructure lager (Fig. 1, a) with hardness of 38 HRC; after tempering of this layer at 500 °C the hardness increased to 46 HRC (Fig. 2). The layer welded under AMS1 flux containing 25 % of chromium powder showed 40 HRC hardness. Tempering of the layer at 500 °C – 600 °C decreased the hardness, and no secondary hardening was noticed. Etching of the specimen with 4 % nitrogen acid spirit solution did not show microstructure of the layer, and only reagent for stainless steel etching etched microstructure (Fig. 1, b); it was martensitic.

In the microstructure of layers welded under AMS1 flux with graphite and chromium powder, bright dendrits (martensite and retained austenite) and interdendritic eutectic (Fig. 1, c and d) may be seen. At tempering the highest hardness was obtained (up to 57 HRC) for the layer with larger carbon amount, because retained austenite transformed to martensite, and, due to higher carbon amount, more intensive dispersion hardening had took place.

The precipitation of stable carbides such as Mo_2C and WC leads to a secondary hardening (hardness increase up to 66 HRC) during tempering of high alloyed steel in the range of 500 °C to 600 °C [12].

Harder layers obtained when Ст3 steel was subjected to overlay welding with Св 08 wire under AMS1 flux mixed with graphite, chromium, molybdenum and the modifiers SiCaBa (15 % – 20 % Ca, 8 % Ba, 2 % – 3 % Al) powder (Fig. 3). Changing SiCaBa powder amount in the flux from 10 % to 21 %, hardness of the surfacing layers was increased from 50 HRC to 65 HRC; tempering at the temperature 500 °C increased hardness even more: from 59 HRC to 67 HRC. The increase of SiCaBa powder amount in the flux resulted formation more carbide phase in the overlay layer (Fig. 4), which microhardness was 8000 MPa.

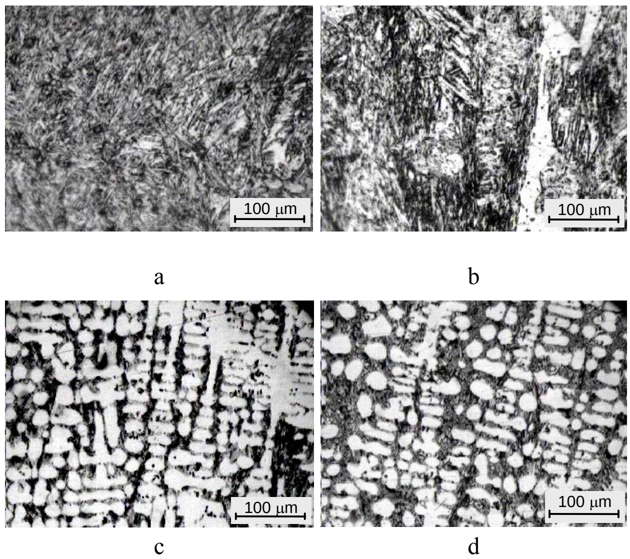

Fig. 1. Microstructures of layers obtained in overlay welding of Ст3 steel by Св 08 wire under the AMS1 flux containing 11 % graphite (a), 25 % chromium (b), 6.5 % graphite and 26.5 % chromium (c), 10 % graphite and 25.5 % chromium powder (d)

Composition of the mixture, mass. %			
Curve	Flux	Graphite	Chromium
1	64.5	10.0	25.5
2	67.0	6.5	26.5
3	87.0	7.5	15.5
4	89.0	11.0	–
5	75.0	–	25.0

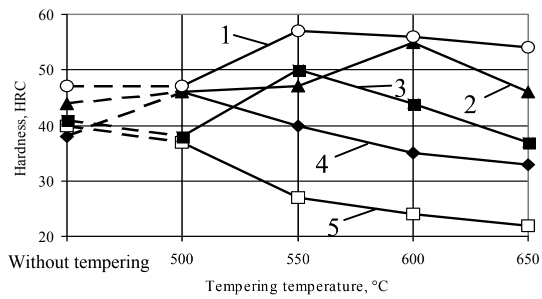

Fig. 2. Dependence of layers hardness on tempering temperature of Ст3 steel subjected to overlay welding with Св 08 wire under the AMS1 flux mixed with graphite and chromium powder

In order to obtain resistant to abrasive wear layers, the steel is subjected to surfacing with materials containing tungsten. Tungsten and carbon formats high resistance, hard carbides inserted in the ductile surfacing matrix.

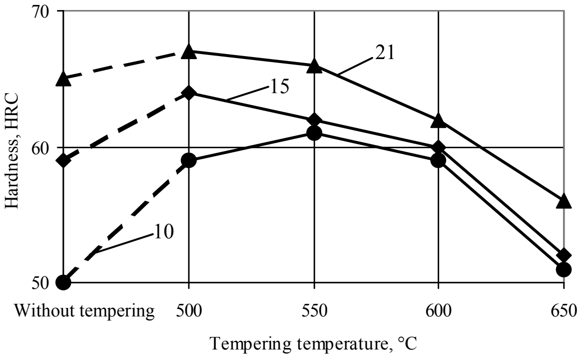

Fig. 3. Dependence of layers hardness on tempering temperature of Ст3 steel subjected to overlay welding with Св 08 wire under the AMS1 flux mixed with graphite (10 %), chromium (10 %), molybdenum (16 %) and SiCaBa (10, 15 and 21 %) powder. Numbers at the curves show SiCaBa powder amount in percents in the flux

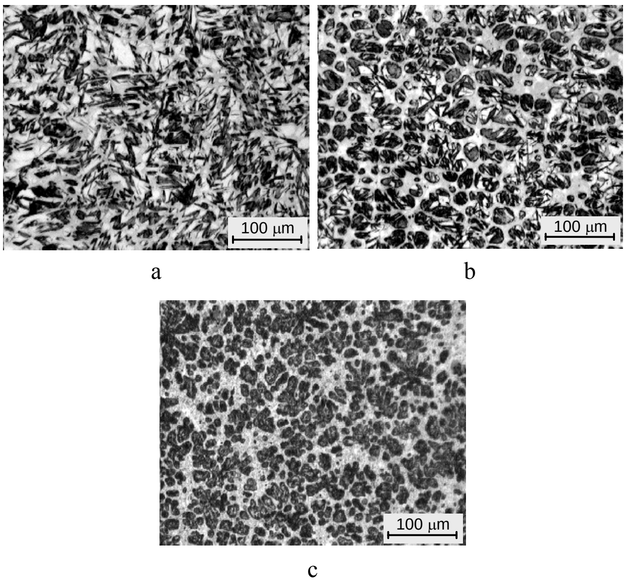

Fig. 4. Microstructures of layers obtained in overlay welding of Ст3 steel by Св 08 wire under the AMS1 flux containing 10 % graphite, 10 % chromium, 16 % molybdenum and varying amount of SiCaBa powder: a – 10 %, b – 15 %, c – 21 %

WC-8 % Co powder assigned for hard metals production was used in our tests. Besides, such powder can be obtained by milling used BK-8 (Russian grade) hard metal plates.

Overlay welding of Ст3 steel by Св 08 wire under AMS1 flux mixed with WC-8 % Co powder resulted layers, which hardened during of tempering. It means that the layers were alloyed enough by tungsten. Besides, melting of WC-8 % Co powder have alloyed the layers by cobalt and enriched by carbon; from AMS1 flux containing more than 50 % of SiO_2 and MnO, the manganese, witch has the property to increase amount of retained austenite, get into the layer.

Tempering at the temperature 600 °C mostly increased the hardness (to 62 HRC) of the layer welded under the AMS1 flux containing 52 % WC-8 % Co powder (Fig. 5).

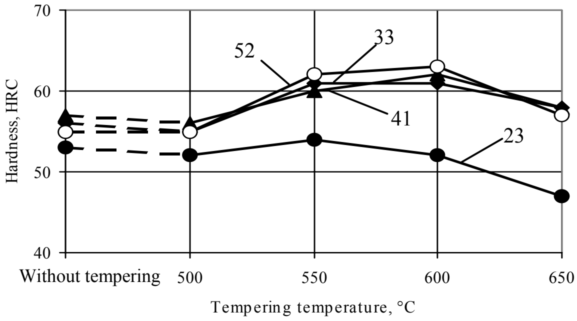

Fig. 5. Dependence of layers hardness on tempering temperature of Ст3 steel subjected to overlay welding by Св 08 wire under the AMS1 flux mixed with WC-8 % Co powder. Numbers at the curves show WC-8 % Co powder percentage amount in the flux

Harder layers (Fig. 6) obtained when AMS1 flux besides WC-8 % Co powder contained modifier's SB-5 (Russian grade) (68 % Si, 1.5 % Al, 1.5 % Ca, 2 % – 3 % Ba) powder. Tempering at 550 °C temperature the hardness of layers increased to 63 HRC. When in the flux composition was 10 % SB-5 modifier's powder, the layer in course of cooling after welding has hardened to 64 HRC, and tempering decreased the hardness of the layers (there was no secondary hardening). In the microstructure of the layer produced by welding under AMS1 flux, containing WC-8 % Co powder and no modifier SB-5 powder, dendrites of martensite and retained austenite are seen (Fig. 7, a). Addition into the flux 3 % of SB-5 powder, decreased size of dendrites, and addition 6 % and more of this powder, results disappearance of the dendrites from the microstructure (Fig. 7, c and d). In the layer welded under the AMS1 flux mixed with WC-8 % Co (52 %) and SB-5 (10 %) powder hard carbides (microhardness 12000 MPa, bright areas in the Fig. 7, d) are noticed.

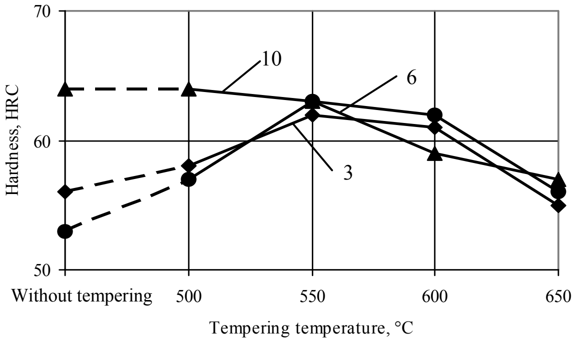

Fig. 6. Dependence of layers hardness on tempering temperature of Ст3 steel subjected to overlay welding by Св 08 wire under the AMS1 flux mixed with WC-8 % Co (52 %) and SB-5 (3, 6 and 10 %) powder. Numbers at the curves show percentage amount of SB-5 powder in the flux

In course of welding the AMS1 flux is alloying the layer with manganese, which improves hardenability. Aiming to obtain more manganese alloyed layer, besides WC-8 % Co (29 %) and graphite (6 %) the Fe-70 % Mn powder was mixed into the flux. Chemical composition of surfacing layers is presented in Table 1.

Table 1. Chemical composition of surfacing layers

Amount of Fe-70 % Mn powder in AMS1 flux, %	Amount of elements, mas. %							
	C	Si	Mn	Cr	Mo	V	Co	W
0	0.95	1.25	1.92	0.06	0.05	0.02	0.95	10.50
10	1.02	1.57	6.04	0.08	0.08	0.04	1.27	10.59

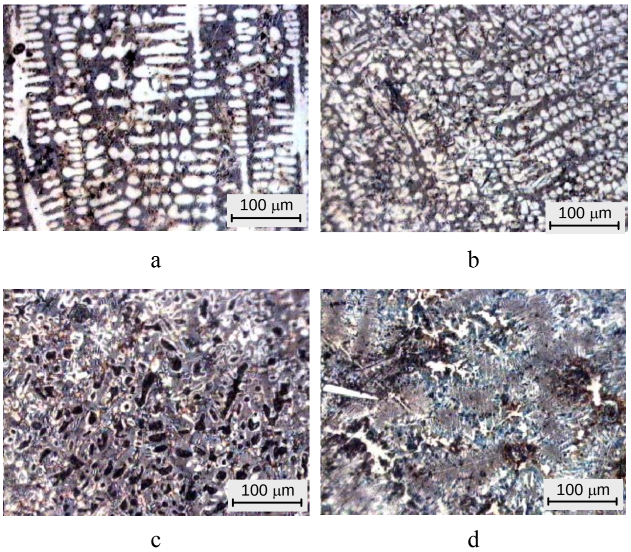

Fig. 7. Microstructures of the layers obtained in overlay welding of Ст3 steel by Св 08 wire under the AMS1 flux containing 52 % WC-8 % Co and SB-5 powder in the allowing amount, %: a – 0, b – 3, c – 6, d – 10

Manganese addition contributes to the strength and hardness of steel, but to a lesser extent than carbon and, in addition, favourably affects forgeability and weldability [13]. Manganese is a solid solution strengthener in steel and is very effective in increasing the hardenability.

Manganese increased heat resistance of the surfacing, i. e., maximum hardening temperature is higher in comparison with the layer containing less manganese (Fig. 8). Overlay welding of Ст3 steel by Св 08 wire under AMS1 flux, containing more Fe-70 % Mn powder, resulted more carbides in the layer. In the microstructure (Fig. 9, b) bright areas show carbides; their microhardness is 7000 MPa.

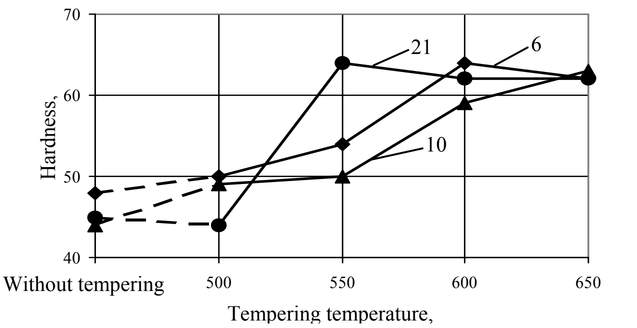

Fig. 8. Dependence of layers hardness on tempering temperature of Ст3 steel overlayed by Св 08 wire under the AMS1 flux mixed with graphite (6 %), WC-8 % Co (29 %) and Fe-70 % Mn powder. Numbers at the curves show percentage amount of Fe-70 % Mn powder in the flux

Overlay welding often is used in order to restore parts size or to increase wear resistance. Abrasive wear tests enabled us to evaluate wear resistance of the surfacing in comparison with hardened tool steels (Fig. 10). Surfacing layer as well as high alloyed carbides containing Х12М steel is 3 – 4 times higher wear resistant than У8 and ХВГ (Russian grades) steels.

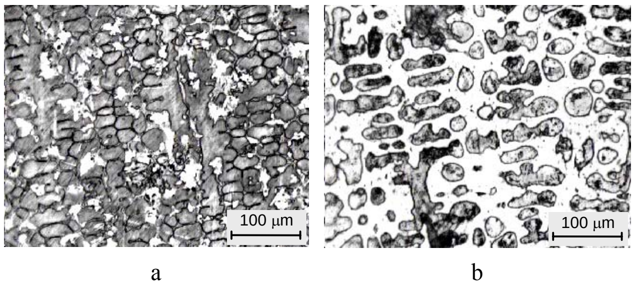

Fig. 9. Microstructures of the layers produced by overlay welding of Ст3 steel with Св 08 wire under the AMS1 flux containing 29 % WC-8 % Co, 6 % graphite and varying amount of Fe-70 % Mn powder: a – 0 %, b – 10 %

Urgent nowadays problem is saving of materials and energetic resources; this can help in solution of environment pollution and a global temperature increase tasks. Materials can be saved restoring used parts and strengthening their surfaces by use of overlay welding. Great amount of materials can be saved using for overlay welding secondary raw materials.

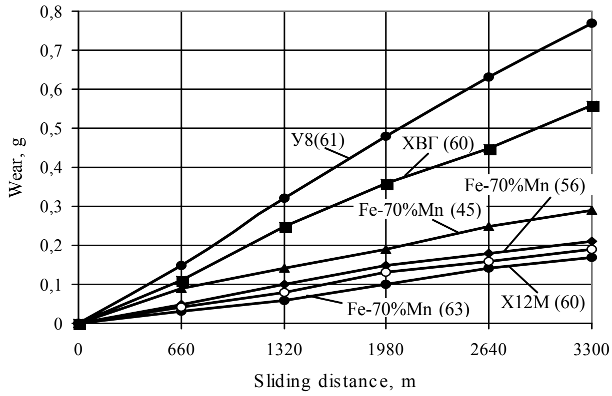

Fig. 10. Comparison of the wear dependence on sliding distance for standard tools steel and the layer welded under the AMS1 flux containing 29 % WC-8 % Co, 6 % graphite and 10 % Fe-70 % Mn powder. Numbers in parenthesis show hardness (HRC)

Grinded glass powder was used for arc surfacing instead of standard flux. Aiming to change composition and microstructure of the surfacing layer glass powder was mixed with milled grinding wheels SiC and B_4C powder and hard metal T15K6 powder. Hardness of the layers was increased insert into welding composition graphite, chromium and Fe-70 % Mn powder.

Composition of the mixture, mass. %						
Curve	Glass	Graphite	Fe--70 % Mn	Cr	T15K6 (Russian grade)	Grinding wheel
1	40.0	–	–	–	60.0	–
2	–	–	15.0	–	–	SiC 85.0
3	46.0	8.0	–	23.0	–	B_4C 23.0

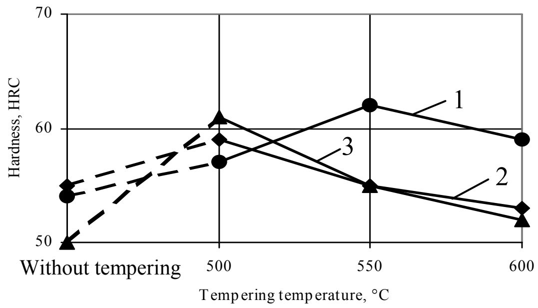

Fig. 11. Dependence of the layers hardness on tempering temperature of Cт3 steel subjected to overlay welding by Cв 08 wire under the mixture composed of glass, graphite, Fe-70 % Mn, chromium, T15K6, SiC and B_4C powder

Overlay welding of Cт3 steel by Cв 08 wire arc under glass (40 %) and T15K6 hard metal (60 %) powder mixture resulted the layer, which after tempering at 550 °C had hardened to 62 HRC (Fig. 11). Surfacing of Cт3 steel with glass (46 %), graphite (8 %), chromium (23 %) and B_4C (23 %) powder mixture, the layer of 50 HRC hardness was obtained; tempering of this layer at 500 °C temperature increased hardness to 61 HRC. Hard enough layer (59 HRC) was obtained, when mixture of Fe-70 % Mn (15 %) and SiC (85 %) powder had been melted in the arc.

4. CONCLUSIONS

1. Overlay welding of Cт3 steel under the AMS1 flux mixed with chromium and graphite powder enables to obtain layer of 57 HRC hardness.
2. High hardness layers (to 67 HRC) can be produced by overlay welding of Cт3 steel under AMS1 flux mixed with chromium, molybdenum, graphite and modifier SiCaBa powder. Modifier SiCaBa decreases dendritic crystallization.
3. Overlay welding of Cт3 steel under the AMS1 flux mixed with WC-8 % Co and modifier SB5 powder allows to obtain hard (65 HRC) not dendritic microstructure with hard carbides layer.
4. When glass powder is used in overlay welding instead of a flux, the stable arc burning and good liquid metal protection from the air influence is achieved. Hard enough (up to 61 HRC) layers can be obtained, when glass powder is mixed with secondary raw materials SiC, B_4C and T15K6 powder.

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Presented at the 17th International Conference "Materials Engineering'2008"
(*Kaunas, Lithuania, November 06 – 07, 2008*)